REMARKS

Further and favorable reconsideration is respectfully requested in view of the foregoing amendments and following remarks.

Initially, the specification has been amended to correct inadvertent errors, such changes being essentially self-explanatory. However, Applicant notes that the amendment to page 1, line 9 is supported by page 4, line 8.

Claim 5 has been rewritten to clarify the invention, based on the disclosure at, for example, page 4, lines 9-18 of the specification, as a result of which the rejection of claim 5 under the first paragraph of 35 U.S.C. §112 has been rendered moot.

The abstract has been rewritten to conform more to the specification, for example as set forth in the first paragraph on page 4.

Attached hereto is a marked-up version of the changes made to the Specification and claim 5 by the current amendment. The attached pages are captioned "**Version with markings to show changes made.**"

The patentability of the present invention over the disclosures of the references relied upon by the Examiner in rejecting the claims will be apparent upon consideration of the following remarks.

Thus, the rejection of claims 5 and 6 under 35 U.S.C. §102(e) as being anticipated by Yamada et al., as well as the rejection of claims 7 and 8 under 35 U.S.C. §103(a) as being unpatentable over Yamada et al. in view of Fraser et al., are respectfully traversed.

As apparent from amended claim 5, the etching gas employed in the method of the present invention contains nitrogen oxide and hydrogen, or nitrogen oxide and a hydrogen-containing compound.

The Examiner states that Yamada et al. discloses a method of dry etching using methane as a gaseous etchant. This reference fails to anticipate or suggest the present invention, which requires that the etching gas contain nitrogen oxide as well as hydrogen or a hydrogen-containing compound.

Therefore, with regard to claims 7 and 8, even if Fraser et al. is combined with Yamada et al. in the manner suggested by the Examiner, the result of such combination would still fail to suggest the subject matter of these claims.

Therefore, in view of the foregoing amendments and remarks, it is submitted that each of the grounds of rejection set forth by the Examiner has been overcome, and that the application is in condition for allowance. Such allowance is solicited.

Respectfully submitted,

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DRY ETCHING

TECHNICAL FIELD

3 The invention of the present application relates to a dry etching. More specifically, the invention of the present application relates to a dry etching method capable of fine processing an electrically conductive material, a heat transfer material, an electric contact material, etc., consisting of copper, silver, gold, or an alloy containing as a main component
9 at least ~~two~~ one of these metals.

BACKGROUND ART

In general, full advantage of lithography and etching technologies is taken in the field of electronic devices such as ultra LSIs or magnetic devices, and these devices are fabricated by combining these techniques.

15 The etching technique~~s~~ is a technique~~s~~ for fabricating a device which comprises transferring a resist pattern produced by lithography onto an object to be processed, i.e., to a semiconductor thin film, a magnetic thin film, etc., and includes methods such as wet-chemical etching method, argon ion milling method, and reactive ion etching method. Among these etching methods, reactive ion etching method is a kind of dry etching method, and is advantageous in that it enables a most precise

transfer of patterns produced by lithography, and that it is suitable for fine processing. Moreover, it boasts superior etching rate. In view of such advantages, numerous large integrated circuits and semiconductor memories are fabricated by the reactive-ion etching method.

The reactive-ion etching method comprises placing the work piece in a plasma of a reactive gas while applying an electric field thereto, and physically and chemically stripping off successive layers of atoms by the incident ion beams that are irradiated vertically to the surface of the work piece. This method enables anisotropic processing cutting vertically along the boundary of the mask, and hence, it allows transfer of fine and sharp patterns.

In case of reactive-ion etching, firstly, the chemically active species such as the ions or radicals of the reactive gases that are generated in the plasma are adsorbed onto the surface of the work piece and undergo chemical reaction to form a layer of chemical products having a low bonding energy. Since the surface of the work piece are exposed to the impact of the positive ions that are accelerated in the plasma by an electric field and which are vertically incident to the surface, the surface layers that are loosely bonded ~~is~~ are successively stripped off by the sputtering of ions or by the ev~~r~~aporation into vacuum. In this context, the reactive-ion etching process can be regarded as a proc ss in which a chemical reaction and a physical pr cess

proceed simultaneously, and it is characterized by having a selectivity on a specific substance and having anisotropy as 3 such to cut vertically into the surface of the object.

However, despite ~~of~~ the superiority of the reactive-ion etching method over other methods, no effective means has been found for etching copper or gold that are widely used in the electronics, or for silver that is used in abundance as a heat conductive material or an electric contact material. The reason for this is that copper, silver, and gold undergo reaction with various types of etching gases such as CF_4, CCl_4, CCl_2F_2, $CClF_3$, $CBrF_3$, Cl_2, C_2F_6, C_3F_8, C_4F_{10}, CHF_3, C_2H_2, SF_6, SiF_4, BCl_3, PCl_3, $SiCl_4$, HCl, $CHClF_2$, etc., which are developed for etching semiconductor materials, and form reaction products with a bonding energy far higher than semiconducting materials. Thus, the reaction products are less apt to be subjected to a sputtering 16 or an evaporation, and cannot be removed in a plasma.

Under the aforementioned circumstances, wet-chemical etching process or argon ion milling process has been conventionally applied to copper, silver, and gold to fabricate, for instance, a thin film magnetic head, a magnetic sensor, a micro transformer, etc. Furthermore, aluminum has been used for the electrodes and interconnections necessary for semiconductor devices by taking advantage of the ease in applying reactive-ion etching process at the expense of a high electric resistance and a high heat emissi n.

DISCLOSURE OF INVENTION

The invention of the present application has been made in the light of the aforementioned circumstances, and an object of the invention is to provide a dry-etching method capable of fine processing an electrically conductive material, a heat transfer material, an electric contact material, etc., consisting of copper, silver, gold, or an alloy containing as a main component at least one of these metals.

9 According to the invention of the present application, the above problems are solved by providing a dry-etching method comprising etching a metallic surface of copper, silver, gold, or an alloy containing as a main component at least one of these metals by plasma of an etching gas containing at least nitrogen oxide while being reacted with the plasma ~~(Claim 1)~~.

Furthermore, the invention of the present application provides, as a preferred embodiment, a dry-etching method in which the etching gas is a mixed gas of nitrogen oxide and hydrogen
18 or a hydrogen-containing compound ~~(Claim 2)~~; in which the hydrogen-containing compound is one type or two or more types of compounds selected from the group consisting of ammonia, hydrocarbons, halogen-containing hydrocarbons, or hydrogen sulfide ~~(Claim 3)~~, and the mask material to be used in covering the metallic surface on etching is the one selected from the group consisting of titanium, titanium alloys, aluminum, or

aluminum alloys ~~(claim 4)~~.

BRIEF DESCRIPTION OF DRAWINGS

Fig. 1(a) to Fig. 1(f) are each a cross section view showing the dry-etching process steps in practicing the process according to the invention of the present application.

Fig. 2 is a cross section view of an example of a reactive ion etching apparatus suitably used in the dry etching according to the invention of the present application.

Fig. 3(a) to Fig. 3(c) are each an electron micrograph showing the state of a copper or a gold thin film after being subjected to the dry etching according to the invention of the present application.

13 The numerals shown in the figures each represent the follow~~s~~ing:

1 Glass substrate or a dielectric substrate

2 Metallic thin film

3 Resist

4 Mask

5 Reaction vessel

6 Deposition protection plate

7 High frequency electrode

8 Sample holder

9 Zero-potential shield

10 Counter electrod

11 Etching gas inlet

12 Etching gas

13 High voltage radio frequency power supply

3

BEST MODE FOR CARRYING OUT THE INVENTION

In the dry etching according to the invention of the present application, a metallic surface formed of copper, silver, gold, or one alloy containing as a main component at least one of these metals is etched by plasma of an etching gas containing at least nitrogen oxide while being reacted with the plasma. As described above, there is no particular limitation on the etching gas to be used in the process so long as it contains at least nitrogen oxide. The nitrogen oxide as referred herein includes nitrous oxide (N_2O), nitrogen monoxide (NO), and nitrogen dioxide (NO_2). Furthermore, the etching gases refer not only to pure gases, but they can be mixed gases containing other components. In case of a mixed gas, preferred as the other components to be mixed with nitrogen oxide is, for instance, hydrogen (H_2) or a compound containing hydrogen. As a compound containing hydrogen, there can be mentioned as examples, one or two or more of, ammonia (NH_3), a gaseous hydrocarbon such as methane (CH_4), a halogen-containing hydrocarbon (i.e., CX_nH_{4-n}, wherein X represents one or two or more types of a halogen element selected from F, Cl, Br, or I, and n represents an integer of 1 to 3), or hydrogen sulfide (H_2S). Among them, particularly

copper thin film was found to be sharper and smoother. This signifies that the resulting product has less re-deposition layer which the copper thin film removed by the etching causes by again deposit to the side walls.

The selectivity ratio with respect to the titanium mask was found to be approximately 12. The index of anisotropy in etching, i.e., the angle between the bottom plane and the side plane of the copper thin film, was found to be 86°. Furthermore, the etching rate was found to be 120 nm/min.

As a matter of course, the invention according to the present application is not limited by the examples described above, and it should be understood that variations and modifications are acceptable on not only the types of the etching gases, but also the details of the etching, such as the constitution and the structure of the reactive ion apparatus, as well as the operation conditions, etc.

17 Industrial Applicability

As described in detail above, in accordance with ~~any of the Claims 1 to 4 of~~ the present invention ~~application~~, fine processing of copper, silver, gold, or an alloy containing as a main component at least one of these metals, become possible by means of reactive-ion etching method. In addition to this, in accordance with ~~Claim 4 of~~ the invention ~~of the present application~~, ther is provided a mask having excellent stability

and fre from ~~the~~ corrosion by the plasma of the etching gases wherein the etching gases contain~~ing~~ at least nitrogen oxide and are usable for copper, silver, gold, or an alloy containing as a main component at least one of these metals.

4

ABSTRACT

A metallic thin film of copper, silver, gold, or one alloy s lected from alloys containing as a main component at least one of these metals is etched by plasma of an etching gas containing at least nitrogen oxide while being reacted with the plasma, whereby making it possible to fine-process electrically conductive materials, heat-transfer materials and electric-contact materials ~~consisting of an alloy containing as a main component~~ made of copper, silver, gold or an alloy containing as a main component at least ~~two~~ one of these metals.

Version with Markings to Show Changes Made

(Amended) 5 ~~(New)~~. A dry etching method comprising etching a metallic surface of copper, silver, gold, or an alloy containing as a main component at least one of these metals by plasma of an etching gas containing ~~at least~~ nitrogen oxide and hydrogen~~,~~ or nitrogen oxide and a hydrogen-containing compound ~~free from halogen atoms~~ while being reacted with the plasma.